Incorporating Ecological Concepts and Biological Criteria in the Assessment and Management of Urban Nonpoint Source Pollution

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Abstract

The health and well-being of the aquatic biota in surface waters are important barometers of how effectively we are achieving the goals of the Clean Water Act (CWA); namely, the maintenance and restoration of biological integrity and the basic intent of water quality standards. Yet, these tangible products of the CWA regulatory and water quality planning and management efforts are frequently not linked nor equated with the more popularized notion of chemical-physical water quality criteria and other surrogate indicators and endpoints. Simply stated, biological integrity is the *combined* result of chemical, physical, and biological processes. Nowhere in water quality management and assessment is the interaction of these three factors more apparent than with nonpoint sources. Management efforts that rely solely on comparatively simple chemical-physical water quality criteria surrogates frequently do not result in the full restoration of ecological integrity. Therefore, ecological concepts, criteria, and assessment tools must be incorporated into the prioritization and evaluation of nonpoint source pollution abatement efforts.

Introduction

The monitoring of surface waters and evaluation of the biological integrity goal of the Clean Water Act (CWA) have historically been predominated by nonbiological measures such as chemical-physical water quality (1). While this approach may have fostered an impression of empirical validity and legal defensibility, it has not sufficiently measured the ecological health and well-being of aquatic resources. An illustration of this point was demonstrated in a comparison of the abilities of chemical water quality criteria and biological criteria to detect aquatic life impairment based on ambient monitoring in Ohio. Out of 645 water-body segments analyzed, biological impairment was evident in 49.8 percent of the cases where no impairments of chemical water quality criteria were observed (2). While this discrepancy may at first seem remarkable, the reasons for it are many and complex. Biological communities respond to and integrate a wide variety of chemical, physical, and biological factors in the environment whether they are of natural or anthropogenic origin. Simply stated, controlling chemical water quality criteria alone does not ensure the ecological integrity of water resources (1).

The health and well-being of surface water resources are the *combined* result of chemical, physical, and biological processes (Figure 1). To be truly successful in meeting these goals, monitoring and assessment tools are needed that measure both the interacting processes and the integrated result of these processes (3). This is especially true for nonpoint sources because many of the effects involve the interactions of these factors. Biological criteria offer a way to measure the end result of nonpoint source management efforts and successfully accomplish the protection of surface water resources. Biological communities respond to environmental impacts that chemical-physical water quality criteria alone cannot adequately discriminate or even detect. Habitat degradation and sedimentation are two prevalent impacts of nonpoint source origin that simply cannot be measured by chemical-physical criteria alone. As illustrated by Figure 1, the combination of chemical and physical factors results in surface water use impairments from nonpoint sources.

The Ohio Environmental Protection Agency (EPA) recently adopted biological criteria in its water quality standards (WQS) regulations. These criteria are based on measurable endpoints regarding the health and well-being of aquatic communities. They are further structured into the state's WQS regulations within a system of tiered aquatic life uses from which numerical biological criteria are derived using a regional reference site approach (4-7). These numerical expressions of biological goal attainment criteria are essentially the end

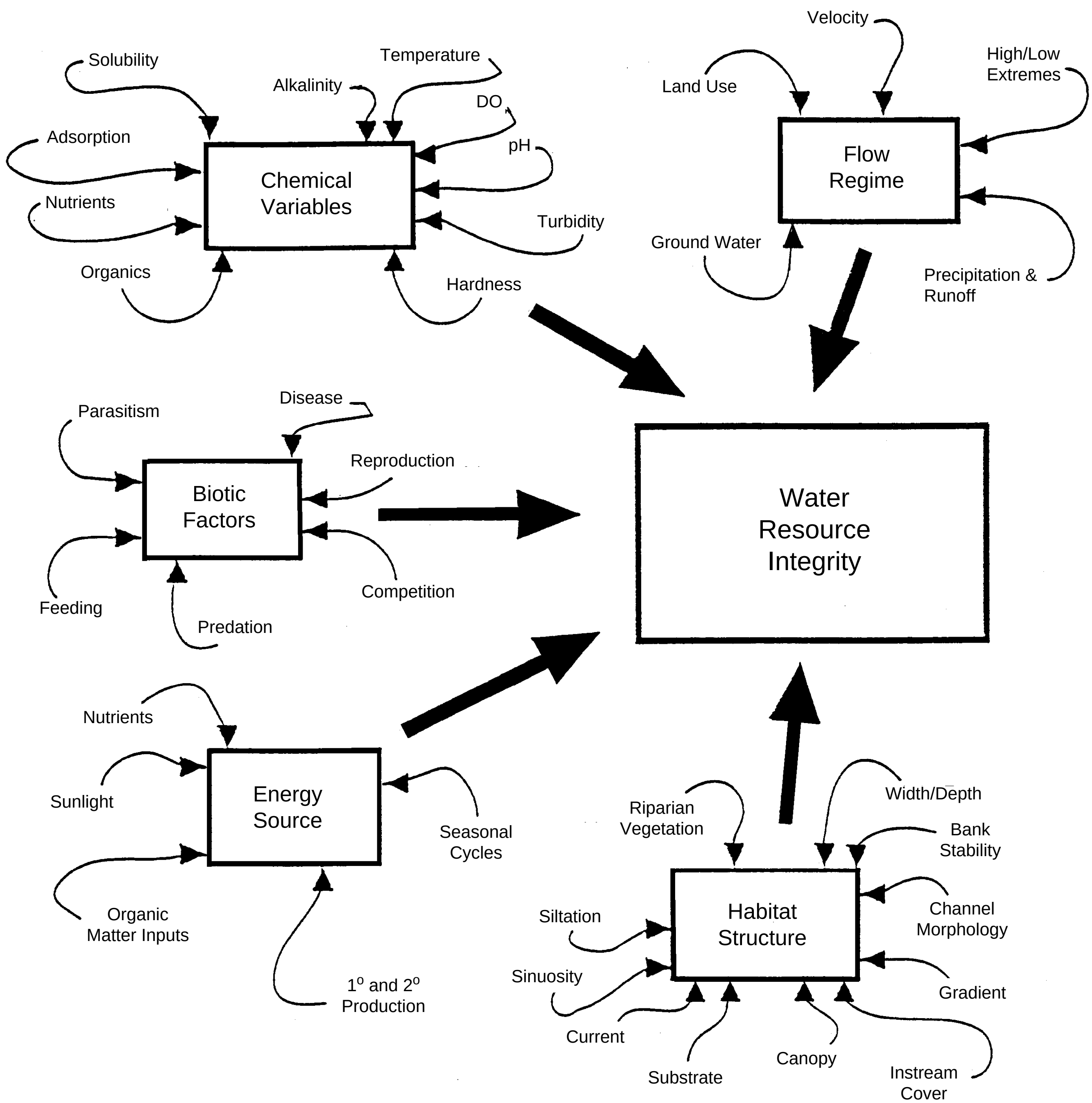

Figure 1. **The five principal factors, with some of their important chemical, physical, and biological components, that influence and determine the integrity of surface water resources (modified from Karr et al. [1]).**

product of an ecologically complex but structured derivation process. While numerical biological indices have been criticized for potentially oversimplifying complex ecological processes (8), distillation of such information to readily comprehendible expressions is both practical and necessary. The advent of new-generation evaluation mechanisms, such as the Index of Biotic Integrity (IBI) (1, 9, 10), the Index of Well-Being (Iwb) (11, 12), the Invertebrate Community Index (ICI) (5), and similar efforts (13-16), has filled important practical and theoretical gaps not always fulfilled by previously available single-dimension indices. Multimetric evaluation mechanisms, such as the IBI, extract ecologically relevant information from complex biological community data while preserving the opportunity to analyze such data on a multivariate basis. The problem of biological data variability is also addressed within this system. Variability is controlled by specifying standardized methods and procedures (17) that are then compressed through the application of multimetric evaluation mechanisms (e.g., IBI, ICI) and stratified by accounting for regional and physical variability and potential (e.g., ecoregions, tiered aquatic life uses). The results are evaluation mechanisms, such as the IBI and ICI, that have acceptably low replicate variability (18-20).

Ecoregional Biocriteria and Determination of Use Attainment

Biological criteria can play an especially important role in nonpoint source assessment and management because they directly represent an important environmental goal and regulatory endpoint (i.e., the biological integrity goal of the CWA). Numerous studies have documented this capability. Gammon et al. (21) documented a "gradient" of compositional and functional shifts in the fish and macroinvertebrate communities of small agricultural watersheds in central Indiana. Community responses ranged from an increase in biomass with mild enrichment to complete shifts in community function. Impacts from animal feedlots had the most pronounced effects. In the latter case, the condition of the immediate riparian zone was correlated with the degree of impairment.

Later work by Gammon et al. (22) suggests that nonpoint sources are impeding any further biological improvements observed in larger rivers due primarily to reduced point source impacts. This is similar to observations that Ohio EPA has made in the Scioto River downstream from Columbus. Urban nonpoint source impacts are well known and have also been documented by numerous investigators. Klein (23) documented a relationship between increasing urbanization and biological impairment, noting that the latter does not become severe until urbanization reaches 30 percent of the watershed area. Steedman (24) used a modification of the IBI to demonstrate the influence of urban land use and riparian zone integrity in Lake Ontario tributaries. Steedman developed a model relationship between the IBI and these two environmental factors.

Biological monitoring of nonpoint source impacts and pollution abatement efforts conducted in concert with the use of more traditional assessment tools (e.g., chemical-physical) can produce the type of evaluation needed to determine where nonpoint source management efforts should be focused, what some of the management goals should be, and what determines the eventual success (i.e., end result) of such efforts. At the same time, a well-conceived monitoring program can yield multipurpose information that can be applied to similar situations without the need to perform site-specific monitoring everywhere. This is best accomplished when a landscape-partitioning framework, such as ecoregions (25) and the subcomponents, is used as an initial step in accounting for natural landscape variability. Because of landscape variability, uniform and overly simplified approaches to nonpoint source management often fail to produce the desired results (26).

Biological criteria in Ohio are based on two principal organism groups: fish and macroinvertebrates. Numerical biological criteria for rivers and streams were derived from the results of sampling conducted at more than 350 reference sites that typify the "least impacted" condition within each ecoregion (5, 6). This information was used within the existing framework of tiered aquatic life uses in the Ohio WQS regulations to establish attainable, baseline biological community performance expectations on a regional basis. Biological criteria vary by ecoregion, aquatic life-use designation, site type, and biological index. The resulting criteria for two of the "fishable, swimmable" uses, Warmwater Habitat (WWH) and Exceptional Warmwater Habitat (EWH), are shown in Figure 2.

Procedures for determining the use attainment status of Ohio's lotic surface waters were also developed (5, 27). Using the numerical biocriteria as defined by the Ohio WQS regulations, use attainment status is determined as follows:

- *Full:* Use attainment is considered full if all of the applicable numeric indices exhibit attainment of the respective biological criteria; this means that the aquatic-life goals of the Ohio WQS regulations are being attained.
- *Partial:* At least one organism group exhibits nonattainment of the numeric biocriteria, but no lower than a narrative rating of "fair," and the other group exhibits attainment.
- *Non:* Neither organism group exhibits attainment of the ecoregional biocriteria, or one organism group reflects a narrative rating of "poor" or "very poor," even if the other group exhibits attainment.

Following these rules, a use attainment table is constructed on a longitudinal mainstem or watershed basis. Information included in the table includes sampling location (river mile index), biological index scores, the Qualitative Habitat Evaluation Index (QHEI) score, attainment status, and comments about important site-specific factors such as proximity to pollution sources. An example of how to construct a use attainment table is provided in Table 1.

Aquatic Ecosystems at Risk

Ecosystems that possess or reflect integrity (as envisioned by the biological integrity goal of the CWA) are characterized by the following attributes (1):

- The inherent potential of the system is realized.

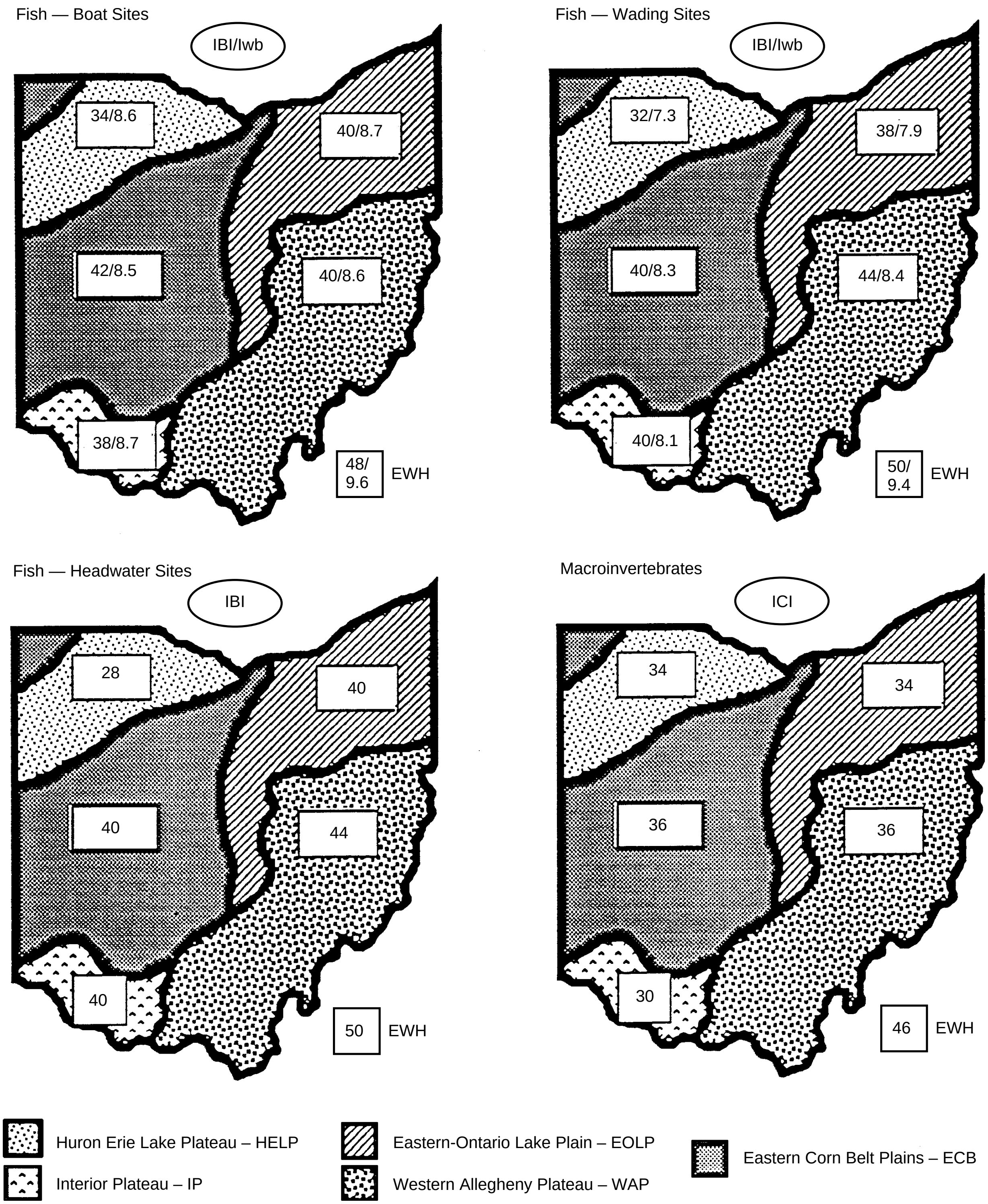

Figure 2. Biological criteria in the Ohio WQS for the Warmwater Habitat (WWH) and Exceptional Warmwater Habitat (EWH) use designations arranged by biological index, site type for fish, and ecoregion. The EWH criteria for each index and site type is located in the boxes located outside of each map.

- The system and its components are stable.
- The system retains a capacity for self-repair when perturbed or injured.
- Minimal or no external support for community maintenance is required.

Thus, ecosystems that are impaired and therefore lack integrity have had their capacity to withstand and rapidly recover from perturbations exceeded. Impaired ecosystems are likely to become even further degraded due to incremental increases in stress.

Many rivers and streams nationwide fail to exhibit the characteristics of healthy ecosystems. Recent estimates indicate that as many as 98 percent of lotic ecosystems are degraded to a detectable degree (29). Karr et al. (30) illustrated the extent to which the Illinois and Maumee River basin fish communities have declined during the past 50 years: two-thirds of the original fauna were lost from the former and more than 40 percent from the latter. Losses of naiad mollusks and crayfish have been even greater. In Ohio, long-term declines in fish communities have been extensively documented by Trautman (31). More recent information indicates that the fraction of the fish fauna that is imperiled or declining has increased from 30 to 40 percent since 1980 (32). This information indicates that lotic ecosystems are threatened in both Ohio and nationwide, an indication that existing frameworks for water resource protection and management have been essentially ineffective in preventing large-scale losses of ecological integrity. This is particularly true for ecosystems affected by habitat degradation, riparian encroachment, excess sedimentation, organic enrichment, and nutrient enrichment. All or most of these forms of degradation are evident in areas affected by urban nonpoint sources.

Urban Nonpoint Source Pollution in Ohio

Urban watersheds in Ohio have exhibited a familiar and well-known legacy of aquatic resource degradation. Few, if any, functionally healthy watersheds exist in the older, heavily urbanized parts of the Midwest. Good quantitative estimates of the proportion of surface waters that are degraded by urbanization are lacking, however, particularly for headwater streams. It is also widely perceived that the restoration of beneficial aquatic life uses in most heavily urbanized areas is not practically attainable. This in itself presents a barrier to any notion of attaining existing use designations or upgrading use designations for waters classified for less than fishable and swimmable uses. The assignment of appropriate aquatic life and recreational uses is a challenge that Ohio EPA has dealt with over the past 15 years.

Urban and suburban development activities that have the greatest impacts on aquatic life in Ohio include the wholesale modification of watershed hydrology, riparian vegetation degradation and removal, direct instream habitat degradation via channelization, construction and other drainage enhancement activities, sedimentation and siltation caused by stream-bank erosion (which is strongly linked to riparian encroachment), and contributions of chemical pollutants. Statewide, urban and suburban sources are responsible for impairment (major and moderate magnitude sources) in more than 927 miles of streams and rivers and more than 23,000 acres of lakes, ponds, and reservoirs (32). These activities also threaten existing use attainment in nearly 160 miles of streams and rivers and may be a potential problem in more than 4,380 miles of streams and rivers that have not yet been fully monitored and evaluated (33).

While much attention is generally given to toxic substances in urban nonpoint source runoff, evidence suggests that nontoxic effects are more widespread, at least in Ohio and the Midwest. The second leading cause of impairment identified by the 1992 Ohio Water Resource Inventory, sedimentation (or siltation) resulting from urban and other land-use activities is the most pervasive single cause of impairment from nonpoint sources in Ohio. Sedimentation is responsible for more impairment (over 1,400 miles of stream and rivers and 23,000 acres of lakes, ponds, and reservoirs) than any other cause except organic enrichment/dissolved oxygen, with which it is closely allied in urban and agricultural areas. Since Ohio conducted the Ohio Water Resource Inventory in 1988 (34), this cause category has surpassed ammonia and heavy metals in rank. If the statewide monitoring database were distributed more equally across the state, sedimentation would likely be found to be the leading cause of impairment.

Although sediment deposition in both lotic and lentic environments is a natural process, it becomes a problem when the capability of the ecosystem to “assimilate” any excess delivery is exceeded. Sediment deposited in streams and rivers comes primarily from stream bank erosion and in runoff from upland erosion. The effects are much more severe in streams and rivers with degraded riparian zones and low gradient. Given similar rates of erosion, the effects of sedimentation are much worse in channel-modified and riparian zone-degraded streams than in more natural, intact habitats. In channel-modified streams, incoming silt and sediment remain within and continue to degrade the stream channel, instead of being deposited in the immediate riparian “floodplain” during high flow periods (35). This also adds to and increases the sediment bedload that continues to affect the substrates long after the runoff events have ceased.

One of the more prevalent results is substrate embeddedness, which occurs when an excess of fine materials, particularly clayey silts and fine sand, fills the otherwise open interstitial spaces between larger substrates (Figure 3). In extreme cases, the coarser substrates may be “smothered”; in other cases, the substrate can be cemented together, or “armor plated.” In either event, the principal ecological consequence is the loss of available benthic surface area for aquatic organisms (particularly macroinvertebrates) and as a location for the development of fish eggs and larvae. The soft substrates afforded by the increased accumulation of fine materials also provide an excellent habitat for the growth of undesirable algae. Thus, to successfully abate the adverse impacts of sediment, we need to be as concerned with what each event leaves behind as

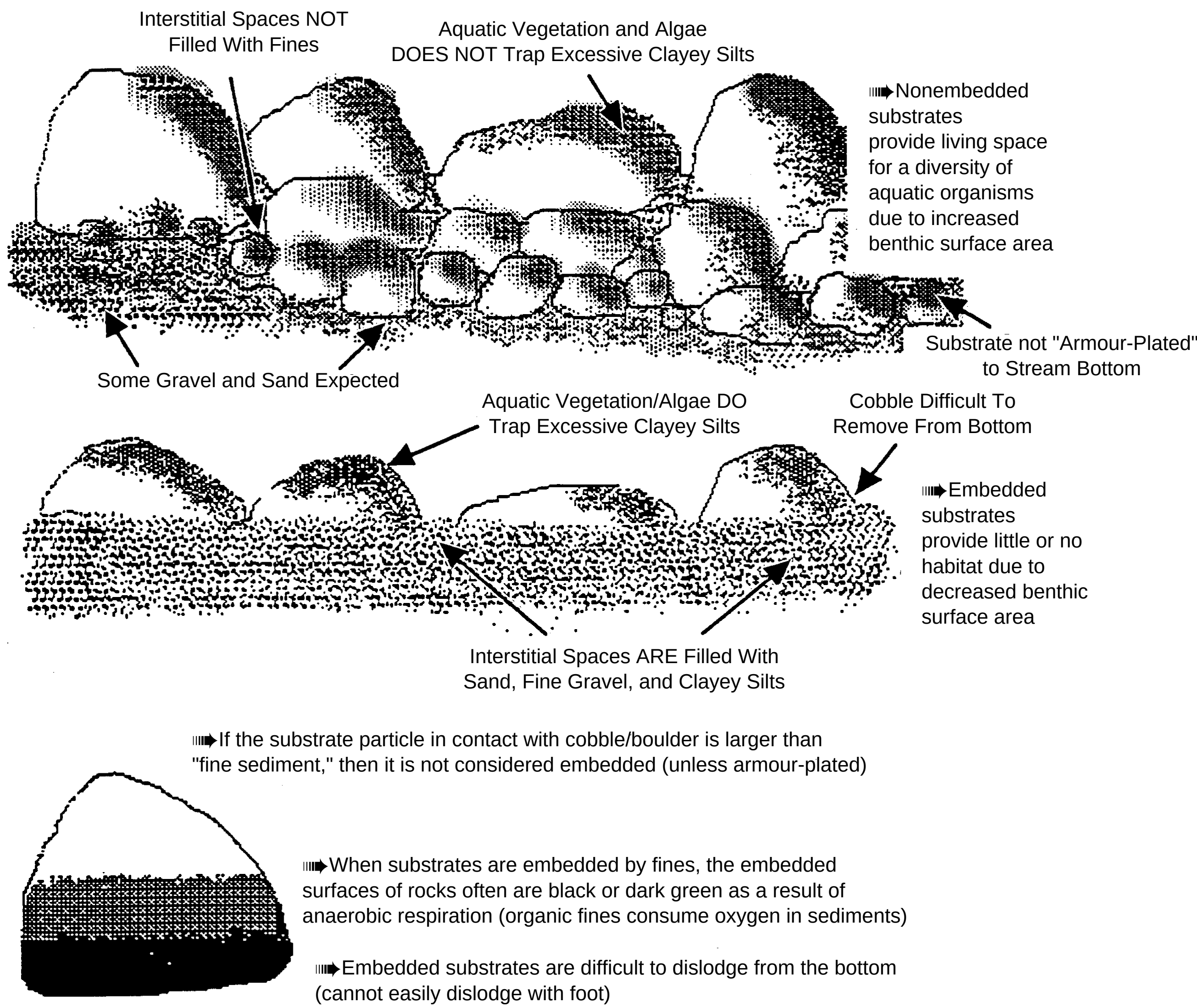

Figure 3. Characterization of substrate embeddedness with some of the key structural signatures and a summary of some of the ecological impacts of this form of stream substrate degradation.

much as with what takes place in the water column during each event.

The effects of sedimentation on aquatic life are the most severe in the ecoregions of Ohio where:

- Erosion and runoff are moderate to high.
- Clayey silts that attach to and fill the interstices between coarse substrates are predominant.
- Streams and rivers lack the ability to expel sediments from the low-flow channel, which results in a longer retention time and greater deposition of silt in the most critical habitats.

Estimates of gross erosion alone do not always correlate with adverse impacts to aquatic communities, although this is a frequently cited criterion for prioritizing nonpoint source management efforts. Some of the areas of Ohio that have the highest rates of gross erosion (e.g., East Corn Belt Plain, Interior Plateau, and Western Allegheny Plateau ecoregions) also have some of the most diverse and functionally healthy assemblages of aquatic life at the least affected reference and other sites (32). Many of the streams in these ecoregions have relatively intact riparian and instream habitat and thus are “buffered” against the naturally erosive conditions. The detrimental effects of sedimentation seem to be the worst in areas of the state where the proportion of clayey silts are highest, stream gradient is the lowest, and riparian encroachment and modification are extensive (i.e., Huron/Erie Lake Plain and portions of the East Corn Belt Plain and Erie/Ontario Lake Plain ecoregions).

The interaction between nonpoint source runoff and riparian and instream habitat must be appreciated and understood if impacts such as sedimentation are to be effectively dealt with. Figure 4 illustrates the interdependency of the rate of runoff, increased sediment delivery, in-channel habitat degradation, riparian zone condition, and substrate condition. An effect involving any one

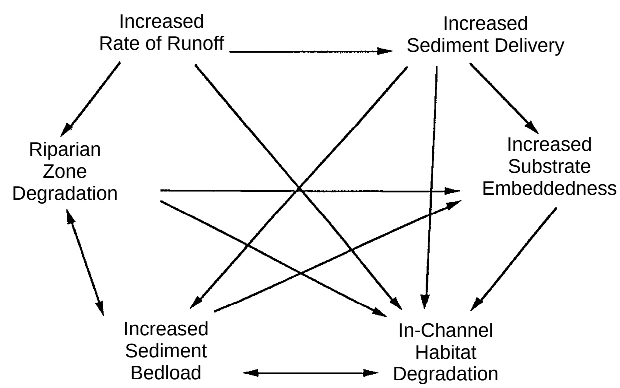

Figure 4. Illustration of the complex interaction of nonpoint source caused changes in hydrology and sediment delivery and how each singly and in combination can degrade instream and riparian habitat.

factor can set off a chain of events that results in cumulative changes reflected by most or even all of the interdependent factors. Two factors that are influenced in the conversion of watersheds by urban development are an increased rate of runoff and increased sediment delivery. These two factors then combine to influence other important aspects of stream habitat, such as riparian zone integrity and increased substrate embeddedness. In effect, a change in one of these factors can result in a cascading chain of events that eventually cause aquatic life use impairment or inhibit the ability of a degraded stream to be successfully rehabilitated. Thus, considerations of previously ignored aspects such as riparian and instream habitat and watershed dynamics must be included in urban nonpoint source assessment and abatement strategies.

The direct and indirect effects of sedimentation and the associated nutrient enrichment are becoming especially apparent in the larger mainstem rivers. Both sediment and nutrient enrichment impacts have largely been overlooked and will not only require a change in the status quo of water quality management but also in the interdisciplinary solutions and information gathering that demonstrates the character and magnitude of these impacts (36).

Bioassessment of Urban Watersheds

Biological criteria and bioassessment methods can and do play a key role in several areas of nonpoint source management. As a basis for determining use impairments, biocriteria have played a central role in the Ohio Nonpoint Source Assessments (33, 37), the biennial Ohio Water Resource Inventory (305b report) (32), and watershed-specific assessments of which Ohio EPA completes from 6 to 12 each year. Biological criteria represent a measurable and tangible goal against which the effectiveness of nonpoint source pollution abatement programs and individual projects can be judged. Biological assessments, however, must be accompanied by appropriate chemical-physical measures, land-use considerations, and source information necessary to establish linkages between the land-use activities and the instream responses.

A great deal of uncertainty exists about the link between steady-state water quality criteria and ecological indicators. While we have observed biocriteria attainment with chemical water quality criteria exceedences in only a fraction of the comparisons, the chemical data are largely from grab samples collected during summer-fall low flow situations. In many cases, we have failed to detect chemical criteria exceedences during low flows, yet biocriteria impairment is apparent. The correspondence of biocriteria attainment with water quality criteria exceedences measured under elevated flows has not been observed with any regularity. Nonetheless, we have surmised that much of the biocriteria nonattainment observed in affected urban watersheds is due to water quality criteria exceedences that have occurred during elevated flow events that preceded the biological sampling. Reaching such a conclusion, however, is made possible only by examining other evidence beyond water column data.

In many urban settings, sediment chemical concentrations frequently are highly or extremely elevated compared with concentrations measured at least-affected reference sites. Contaminated sediments enter the aquatic environment during episodic releases from point sources and during runoff events from nonpoint sources. The correspondence between increasingly elevated sediment concentrations and declining aquatic community performance is demonstrated by Figure 5. A sediment classification scheme derived by Kelly and Hite (38) for Illinois streams was used to classify results for sediment chemical analyses at sites with corresponding biological data. Sediment chemical concentrations are classified as nonelevated, slightly elevated, elevated, highly elevated, and extremely elevated as the concentrations increase beyond the mean concentration at background sites. The results for four heavy metal parameters (arsenic, cadmium, lead, and zinc) commonly encountered in urban settings show that the frequency

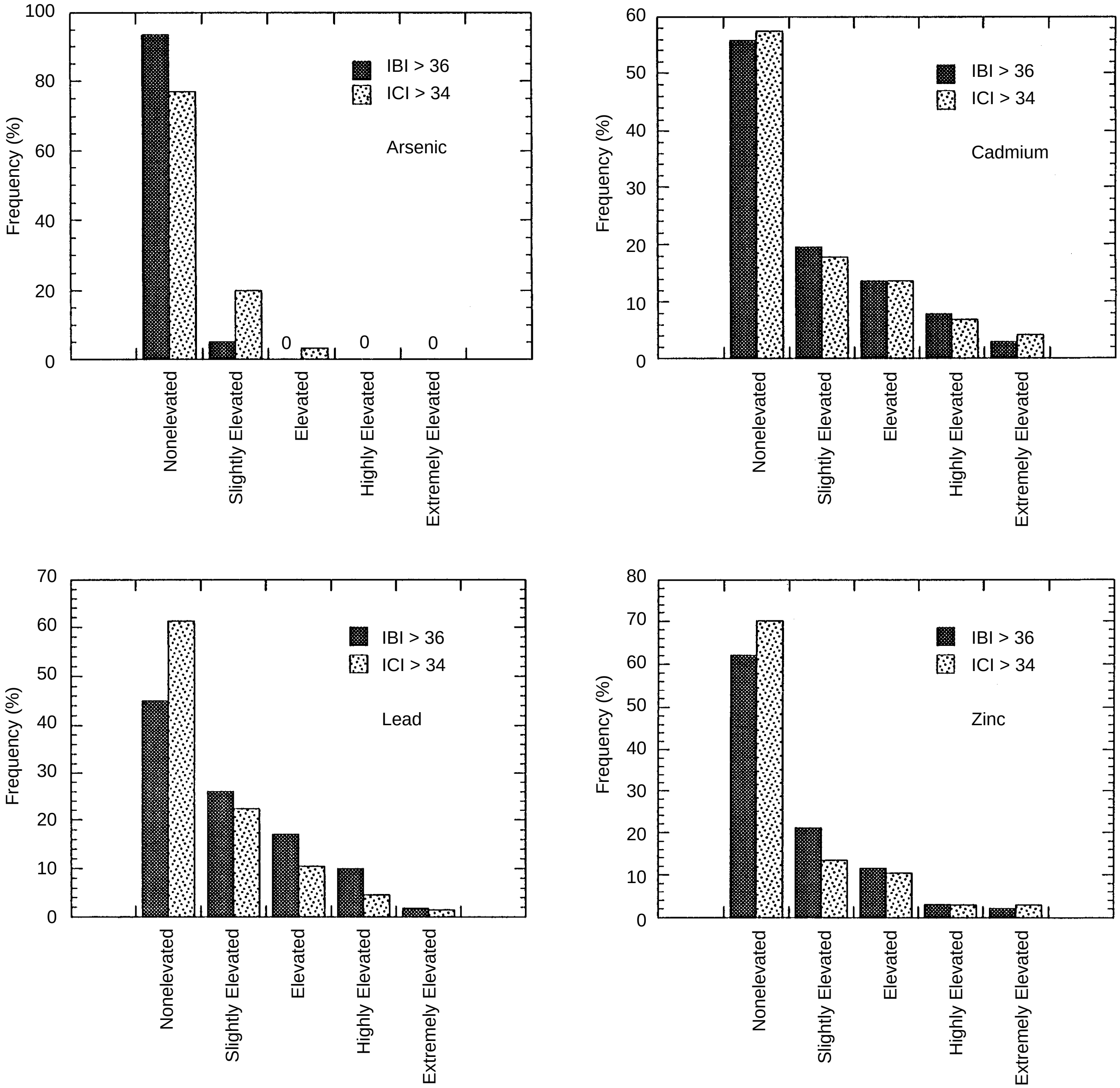

Figure 5. The frequency of occurrence of IBI and ICI scores which attain the warmwater habitat biocriteria under increasingly contaminated levels of four heavy metals in bottom sediments. Based on data collected by Ohio EPA throughout Ohio between 1981 and 1989.

of sites attaining the WWH use designation criteria for the IBI and ICI sharply decline as the sediment concentrations of these metals increase. For arsenic, no sites with highly or extremely elevated concentrations attain the biocriteria. For the remaining three parameters, in a few instances in each case, biocriteria attainment exists with highly elevated or extremely elevated sediment concentrations, but these are exceptions to the overall pattern.

For bioassessments to achieve their maximum effective use in the assessment of urban nonpoint sources, sampling and analysis should be based on a watershed design. An example of the use of biological criteria to evaluate aquatic life-use attainment/nonattainment in an urban watershed involves the Nimishillen Creek basin in northeastern Ohio (Table 1). This watershed is subject to a variety of point and nonpoint source impacts and is extensively affected by intensive urbanization in several

Table 1. Aquatic Life-Use Attainment Status for the Existing and Recommended Aquatic Life-Use Designations in the Nimishillen Creek and Selected Tributaries Based on Data Collected From June to September, 1985

Use Designation	RIVER MILE Fish/ Invertebrate	IBI	MIwb	ICI[a]	QHEI[b]	Attainment Status[c]	Comment
Nimishillen Creek							
WWH	14.2/14.2	30[d]	6.7[d]	22[d]	60	Non	Dst. East and Middle Branches
	12.7/12.7	22[d]	6.0[d]	22[d]	71.5	Non	Cherry Ave.
	11.7/11.7	20[d]	4.8[d]	12[d]	81	Non	Dst. West Branch (Gregory Galvanizing)
	11.2/11.1	17[d]	3.3[d]	8[d]	81.5	Non	Dst. Hurford Run (Ashland Oil)
WWH	10.2/10.3	19[d]	3.1[d]	10[d]	72.5	Non	Ust. Canton WWTP
	8.8/8.8	19[d]	2.3[d]	8[d]	85	Non	Baum Rd.
	6.7/6.7	16[d]	3.6[d]	2[d]	80.5	Non	Howenstine Rd.
	3.2/3.2	24[d]	4.2[d]	6[d]	91	Non	Main St.
	0.6/0.6	20[d]	3.9[d]	0[d]	92	Non	Ust. at mouth
Sherrie (Sherrick) Run							
LRW	5.3/5.3	12[d]	N/A	P[d]	33.5	Non	
WWH	4.1/4.1	17[d]	N/A	P[d]	70 T	Non	Dst. Osnaburg Ditch
	0.1/—	22	N/A	P[d]	52	Non	
Osnaburg Ditch							
MWH	0.7/0.7	15[d]	N/A	P[d]	42 T	Non	Ust. East Canton WWTP
	0.1/0.1	12[d]	N/A	P[d]	39	Non	Dst. East Canton WWTP
Hurford Run							
LRW	2.0/—	12[d]	N/A	—	34.5	Non	Ust. Ashland Oil
	1.8/—	12[d]	N/A	—	27	Non	Dst. Ashland Oil
MWH	1.2/—	12[d]	N/A	—	52.5	Non	Dst. Domer Ditch
WWH	0.3/—	12[d]	N/A	—	66	Non	
	0.1/—	18[d]	N/A	—	50.5	Non	
Domer Ditch							
WWH	0.5/0.4	23[d]	N/A	MG	60	Non	Ust. Timken
	0.1/0.1	18[d]	N/A	P[d]	54.5	Non	Dst. Timken
West Branch Nimishillen Creek							
WWH	5.9/5.9	27[d]	N/A	18[d]	53	Non	At cemetery
	3.2/3.2	17[d]	4.8[d]	20[d]	59.5	Non	Dst. McDowell Ditch
	1.6/1.6	22[d]	5.5[d]	20[d]	43.5	Non	Ust. Tuscarawas St.
	0.8/—	24[d]	6.2[d]	—	34.5	(Non)	Ust. Gregory Galvanizing
	0.1/0.1	21[d]	3.1[d]	12[d]	65	Non	Dst. Gregory Galvanizing
McDowell Ditch							
MWH	1.8/1.8	21[d]	N/A	F	34	Partial	Ust. Everhard Rd.
	0.1/0.1	21[d]	N/A	F	41	Partial	At mouth
Zimber Ditch							
WWH	3.8/3.8	40[ns]	N/A	G	57	Full	Regional reference site
	1.8/2.4	29[d]	N/A	F	42	Non	Dst. Hoover Industrial Park
MWH	0.9/1.1	23[d]	N/A	F	31	Partial	Ust. North Canton Ditch
	0.6/0.6	23[d]	N/A	F	31.5	Partial	Dst. North Canton Ditch
Rettig Ditch							
Undesignated	0.9/0.9	29[d]	N/A	F	39	Non	Channel modified
North Canton Ditch							
LRW	0.1/0.1	32	N/A	P	46	Full	Partially culverted (80-m zone)

Table 1. Aquatic Life-Use Attainment Status for the Existing and Recommended Aquatic Life-Use Designations in the Nimishillen Creek and Selected Tributaries Based on Data Collected From June to September, 1985 (Continued)

Use Designation	RIVER MILE Fish/ Invertebrate	IBI	MIwb	ICI[a]	QHEI[b]	Attainment Status[c]	Comment
Middle Branch Nimishillen Creek							
WWH	11.4/11.4	45	N/A	30[ns]	50	Full	
	10.4/10.4	27[d]	5.8[d]	22[d]	38	Non	Ust. State St.
	8.0/8.0	34[ns]	7.7[ns]	30[ns]	74	Full	Dst. Werner-Church Rd.
	6.8/6.8	35[ns]	8.0	40	47	Full	Regional reference site
	5.0/—	37[ns]	7.6[ns]	—	—	(Full)	Ust. 55th St.
	2.5/2.5	38	8.3	28[d]	—	Partial	Ust. Martindale Rd.
	1.6/—	43	8.5	—	—	(Full)	Dst. State Route 62
	—/0.8	—	—	10[d]	—	(Non)	
	0.2/0.1	28[d]	7.2[d]	14[d]	60	Non	Cookes Park
Swartz Ditch							
MWH	2.6/2.6	26	N/A	F	34	Full	Ust. Smith-Kramer Rd.
	1.2/1.2	33	N/A	P[d]	31	Non	Ust. Church Rd.
	0.2/0.3	34	N/A	F	45.5	Full	Dst. Hartville Ditch
Guiley (Hartville) Ditch							
MWH	—/4.1	—	—	P[d]	—	(Non)	Ust. Teledyne
	3.4/—	26	N/A	—	27	(Full)	Ust. Hartville WWTP
	2.3/2.3	33	N/A	P[d]	32	Partial	Dst. Smith-Kramer Rd.
	0.4/0.4	36	N/A	F	44	Full	Gans Rd.-Dst. Culvert
East Branch Nimishillen Creek							
WWH	8.6/8.6	39[ns]	N/A	40	64.5	Full	Regional reference site
	6.4/6.3	33[d]	6.8[d]	26[d]	51	Non	Ust. J&L Steel
WWH	4.7/4.7	29[d]	6.4[d]	4[d]	80	Non	Dst. J&L Steel
	4.2/4.2	23[d]	3.8[d]	14[d]	66	Non	Dst. Louisville South WWTP
	3.4/2.8	24[d]	4.5[d]	20[d]	66	Non	Dst. Louisville North WWTP
	1.9/1.9	24[d]	5.1[d]	20[d]	67.5	Non	Ust. LTV Steel
	0.1/0.1	31[d]	8.2[d]	14[d]	60.5	Partial	At mouth

Ecoregion Biocriteria: Erie/Ontario Lake Plain

INDEX - Site Type	WWH	EWH	MWH[e]
IBI - Headwaters	40	50	24
IBI - Wading	38	50	24
MIwb - Wading	7.9	9.4	5.8
ICI	34	46	22

[a] Narrative criteria used in lieu of ICI: E = exceptional, G = good, MG = marginally good, F = fair, P = poor.
[b] All QHEI values are based on the most recent version of the index (28).
[c] Use attainment is parenthetically expressed when based on one organism group.
[d] Significant departure from ecoregion biocriteria; poor and very poor results are underlined.
[e] For channel modified areas.
Dst. = downstream
LRW = Limited Resource Waters
MIwb = modified Iwb
MWH = Modified Warmwater Habitat
ns = nonsignificant departure from WWH and EWH biocriteria (4 IBI or ICI units; 0.5 MIwb units).
Ust. = upstream
WWTP = wastewater treatment plant

areas. As with many of the Ohio watersheds that are more heavily affected by point and nonpoint sources, the majority of sampling sites either fail to attain the applicable biological criteria or are only in partial attainment. Out of 57 sampling sites in the entire watershed, only 11 (19 percent) fully attained the applicable biological criteria. These results demonstrate the degree of degradation that exists in most urban watersheds and the multiple source causes.

Another issue of critical importance to the management of urban watersheds is also apparent in Table 1, use attainability. Many of the use designations listed for the various streams of the Nimishillen Creek basin are recommended uses, meaning that a different aquatic life use applied at the time of the sampling. An important objective of the biological sampling conducted by Ohio EPA is to determine the appropriate aquatic life-use designation. If the results of the sampling and data analysis suggest that the existing use designation is inappropriate (or the stream is presently unclassified), the appropriate use is recommended. These recommendations are then proposed in a WQS rulemaking procedure and adopted after consideration of public input.

Figure 6 illustrates the relative distribution of IBI scores based on biological monitoring conducted by Ohio EPA in several urban and suburban watersheds throughout Ohio. These range in size from relatively small headwater streams (less than a 20-square-mile watershed area) to increasingly larger streams and rivers. For the smaller watersheds, there is a pattern of lower IBI scores and a subsequent loss of biological integrity with an increasing degree of urbanization. The baseline biological criterion for the WWH use designation is not attained by any (or only a few) sampling sites in the older urban watersheds, such as the Cuyahoga River and Little Cuyahoga River of northeastern Ohio and Mill Creek in Cincinnati. The IBI scores in these watersheds are indicative of poor and very poor water resource quality. The Rocky River basin is largely a suburban area of Cleveland upon which municipal wastewater discharges have had an extensive impact, but despite this the basin exhibits higher IBI scores. The highest IBI scores were observed in Rocky Fork (Columbus area), Taylor Creek (Cincinnati area), and Little Miami River (southwest Ohio) tributaries, which have only recently begun to be suburbanized. These three watersheds also lack some of the companion impacts of the older urban areas, namely, combined sewer overflows and industrial discharges.

For the larger streams and rivers, the pattern was similar, with the older urban areas exhibiting the lowest IBI scores and the less urbanized and suburban watersheds exhibiting higher scores, some of which attain the WWH criteria. The major exceptions, however, involve the two large mainstem rivers (Great Miami River and Scioto River) which exhibit higher IBI scores despite flowing within urban settings. This illustrates the influence of river and upstream watershed size on the ability of a river or stream to withstand increased urbanization. Both the Great Miami River and Scioto River mainstems originate in rural areas and are quite large when they enter the Dayton and Columbus urban areas. Thus, stream size relative to the watershed and the influence of land-use patterns are important to understanding and managing local nonpoint source impacts.

Applications to Nonpoint Source Management

Steedman (24) observed the IBI to be negatively correlated with urban land use. The land use within the 10 to 100 km^2 area upstream from a site was the most important in predicting the IBI, which suggests that “extraneous” information was likely included if whole watershed land-use area was used. Steedman (24) also determined that the condition of the riparian zone was an important covariate (a measure of independent variation) with urban land use in addition to other factors, such as sedimentation and nutrient enrichment. A model relationship between these factors and the IBI was developed and provided the basis to predict when the IBI would decline below a certain threshold level with certain combinations of riparian zone width and percent of urbanization. In the Steedman (24) study, the domain of degradation for Toronto area streams ranged from 75-percent riparian removal at 0-percent urbanization to 0-percent riparian removal at 55-percent urbanization. These results indicate that it is possible to establish the bounds within which the combination of watershed land use and riparian zone condition must be maintained for a target level of biological community performance to persist. It seems plausible that such relationships could be established for many other watersheds, provided the database is sufficiently developed not only for biological communities but also for land-use composition and riparian corridor condition. Additionally including the concept of ecoregions and subecoregions should lead to the development of criteria for land use and riparian zones that would ensure the maintenance of biocriteria performance levels in streams and rivers over fairly broad areas without the need to develop a site-specific database everywhere.

Well-designed biological surveys can fit well into the watershed approach to nonpoint source management. Because the biota respond to and integrate all of the various factors that affect a particular water body, they are essentially the end product of what happens within watersheds. The important issue is that ambient monitoring be conducted as part of the nonpoint source assessment and management process, and that it be performed correctly in terms of timing, methods, and design. Monitoring alone is not enough, however. Federal, state, local, and private efforts to remediate nonpoint source impairments must include an interdisciplinary approach that goes beyond water column chemistry impacts to include the cumulative range of factors responsible for ecosystem degradation that has been documented over the past century. Existing regulations and standards have only been locally successful in reducing water resource declines attributable to watershed and riparian zone degradation. Effective protection and rehabilitation strategies require the targeting of large areas and individual sites (39) as well as the

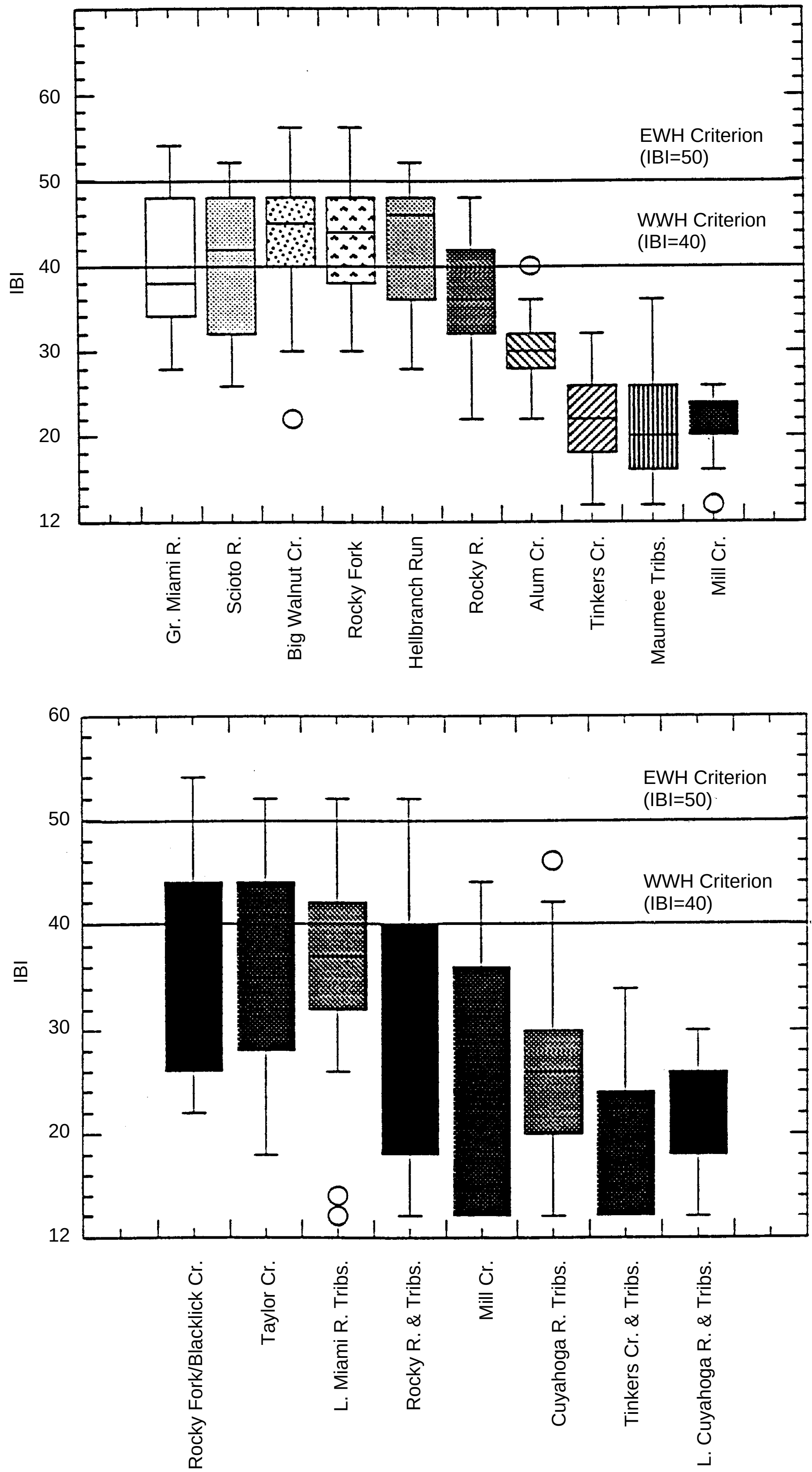

Figure 6. IBI values observed in selected Ohio headwaters streams (drainage area <20 mi.^{2}; upper) and larger Ohio streams and rivers between 1981 and 1992. Box and whisker plots include all values recorded in each stream or stream/river assemblage.

incorporation of ecological concepts in the status quo of land-use management practices and policies.

Ohio EPA has initiated the development of policies that will ensure a holistic approach to nonpoint source management. For example, we have specified a minimum width of two to three times the bank full channel width as necessary to protect riparian zones and ensure the integrity of instream habitat. This also ensures that the ability of the stream to assimilate nonpoint source runoff will be maintained. To be completely successful, however, this measure must be accompanied by the application of best management practices in the uplands. Such an approach goes well beyond a singular concern for the concentration of pollutants in the water column and must be incorporated into the total maximum daily load approach envisioned by the U.S. Environmental Protection Agency as an integral part of urban nonpoint source runoff management.

Thus, it seems that we have a choice in the management of urban nonpoint sources, as portrayed by Figure 7. Extending the traditional process by which we have managed chemical pollutants discharged by point sources during the past 15 to 20 years to nonpoint sources is exemplified by treating streams as once-through flow conduits that are essentially isolated from interactions with the landscape. This is commonly exemplified by simplified mass-balance approaches to establishing water quality-based effluent limitations for point sources using steady-state assumptions. While this approach has been successful in reducing point source loadings of commonly discharged substances, it holds much less promise for highly dynamic inputs from diffuse sources. For nonpoint source management to truly result in the restoration and preservation of biological integrity, we must regard streams as an interactive component of the landscape where multiple inputs and influences act together to determine the health of the aquatic resource.

Urban watershed management and protection issues will continue to develop as new information is revealed and relationships between instream biological community performance and watershed factors are better developed. Nonetheless, some of what we know now should be included in current management strategies. Urban and suburban development must become proactive; that is, developments must be designed to accommodate the features of the natural landscape and include common sense features such as setbacks from riparian zones. Regulatory agencies also share responsibility, particularly in resolving use attainability issues. Watersheds that exhibit the attainment of aquatic life-use biocriteria should be protected to maintain the current conditions. Frequently our attention seems to emphasize high quality or unique habitats; however,

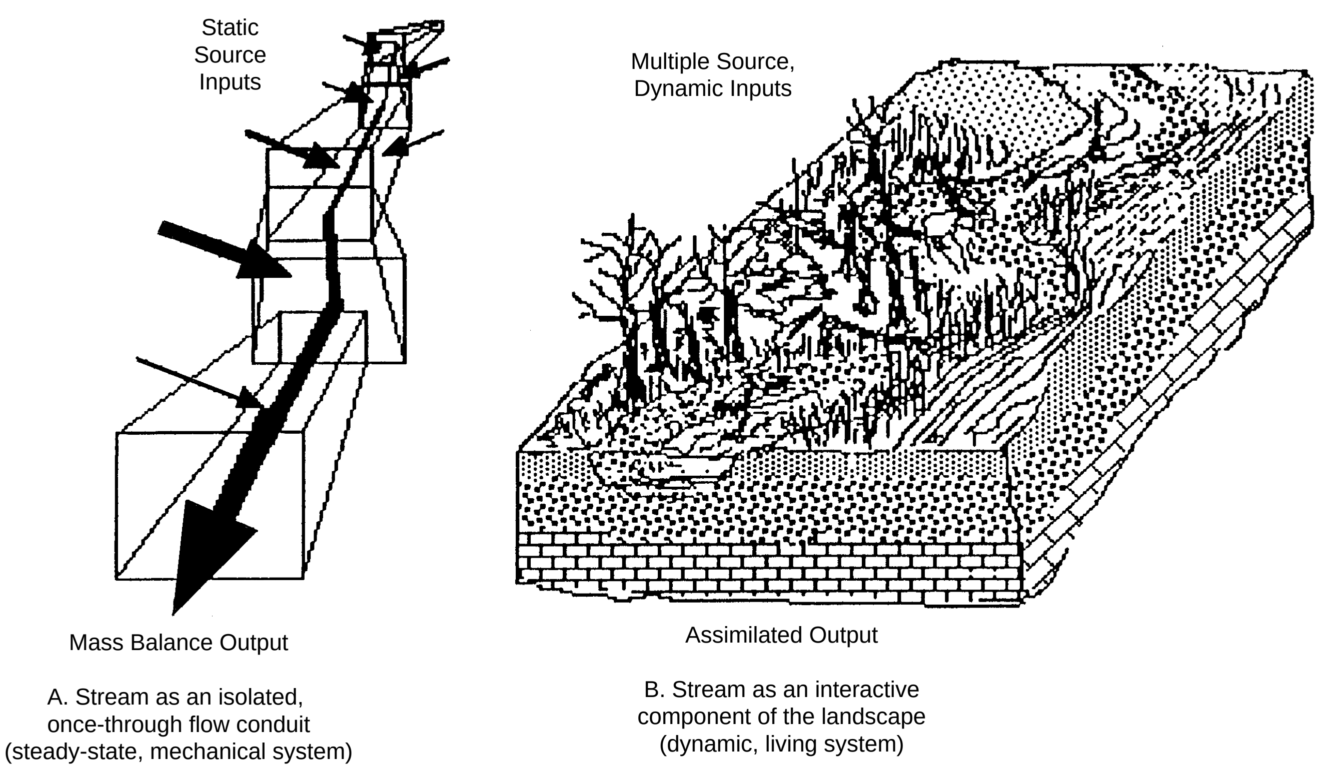

Figure 7. Two views of a stream ecosystem: A. The stream is viewed as an isolated conveyance for static source wastes and runoff with the net water column output as a mass balance function of flow and concentration. B. The stream as an interactive component of the landscape with dynamic and multiple source inputs and assimilated output as affected by the surrounding land use, habitat, geology, soils, and other biotic and abiotic factors.

water quality standards must be maintained where they are presently attained, if even minimally so. Strategies should also include the restoration of degraded watersheds where that potential exists. In systems where the degree of degradation is so severe that the damage is essentially irreparable, minimal enhancement measures should still be required, even though full use attainment is not expected. Biocriteria and bioassessments have an important and central role to play in this process.

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